



Filtration Performance of a NIOSH-Approved N95 Filtering Facepiece Respirator with Stapled Head Straps



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ABSTRACT

Certain NIOSH-approved filtering face piece air purifying respirators are manufactured with stapled head straps. Depending on the manufacturer, these head straps may be stapled to the filter media itself. The staple punctures may cause leakage through the filter media of the respirator, potentially exposing the user to an unacceptable level of contaminant. Nominal particle sizes of Polystyrene Latex (PSL) spheres (0.5, 1, and 2 μm in diameter) were used to challenge four N95 single use respirators of the same model. The stapled areas of the same respirators were sealed with silicon rubber and tested again. A laser particle counter was used to measure the concentration inside and outside of the respirator. The filter efficiencies for unsealed and sealed respirators, at each particle size, were compared to determine if the staple punctures on the filter medium allow penetration of particulates through the stapled areas. The null hypotheses in this study are that there are no differences in efficiencies between unsealed and sealed stapled areas and no differences when testing with different particle sizes of PSL spheres.

Purpose of Study

This study compares the efficiency of an N95 respirator model with stapled head straps before and after sealing the stapled areas of the filter with silicon rubber. It is important to know if the staple punctures cause penetration and if it is of a magnitude that reduces efficiency of the respirator below 95% as mandated by NIOSH for certification.

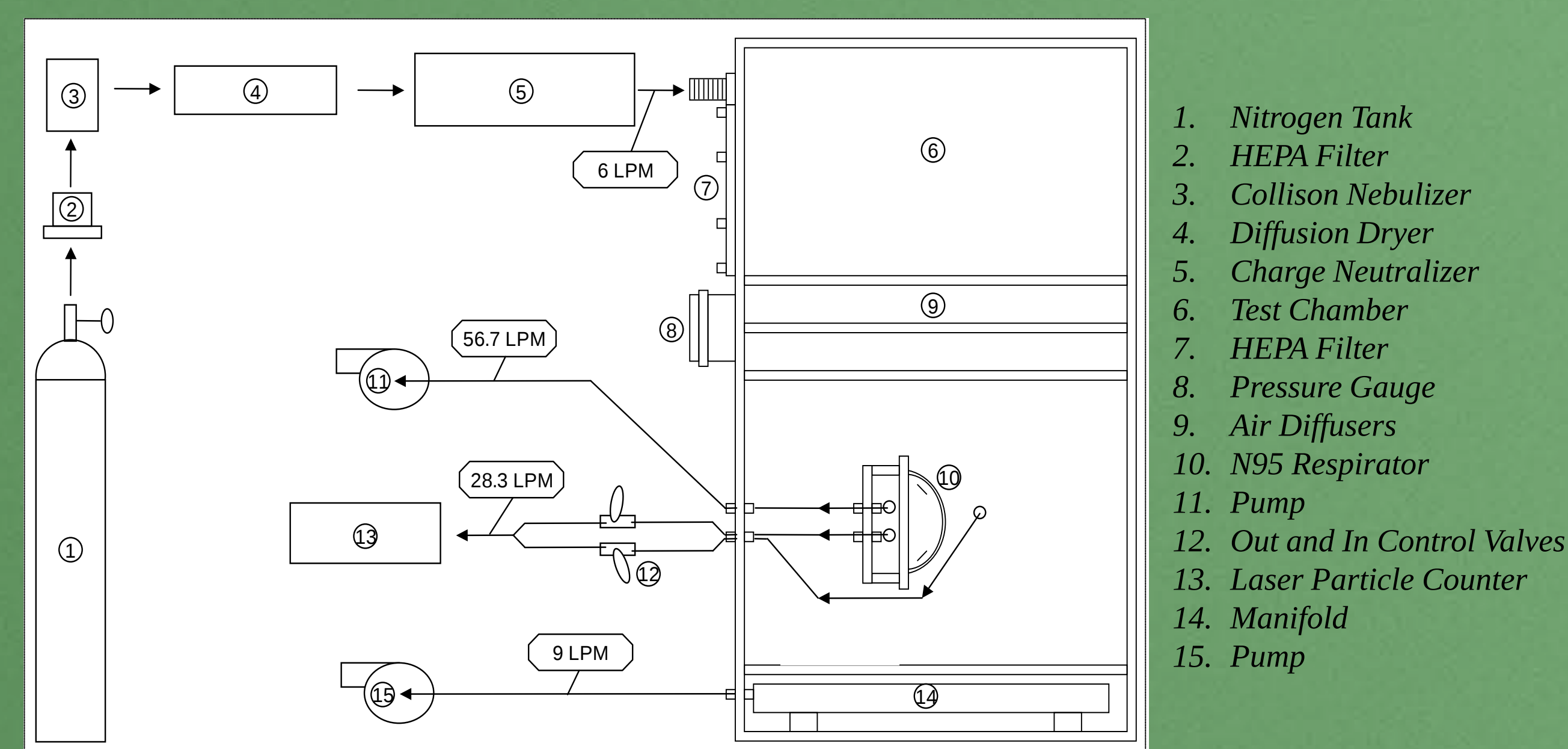


Figure 1. Experimental Design

Experimental Design

Figure 1 shows the experimental design. Compressed nitrogen, at 20 psi, passes through a HEPA filter into a 3-jet Collison nebulizer with a PSL suspension of a known particle size to generate the challenge aerosol. The aerosol cloud exits the nebulizer at 6 LPM and into a diffusion dryer that uses silica gel to absorb water vapor from the aerosol cloud. The relative humidity was maintained below 50%. The aerosol then passes through a Krypton-85 charge neutralizer to equilibrate the charge of the aerosol cloud. Figure 2 and Figure 3 show the components of the generation train. The aerosol mixes with clean air inside the upper compartment of the test chamber (Figure 4-5) and passes through three stainless steel diffusers. The N95 respirator was sealed to a testing assembly (Figure 6) and placed at the lower compartment of the test chamber. Air was sampled from inside and outside the respirator testing assembly and analyzed using a laser particle counter, operating at a 28.3 LPM. To achieve a sample flow rate of 85 LPM through the respirator filter, an additional 56.7 LPM was exhausted through the respirator. Another diffuser was placed beneath the respirator testing assembly above a manifold exhausting 9 LPM.



Figure 2. Generation Train and Test Chamber

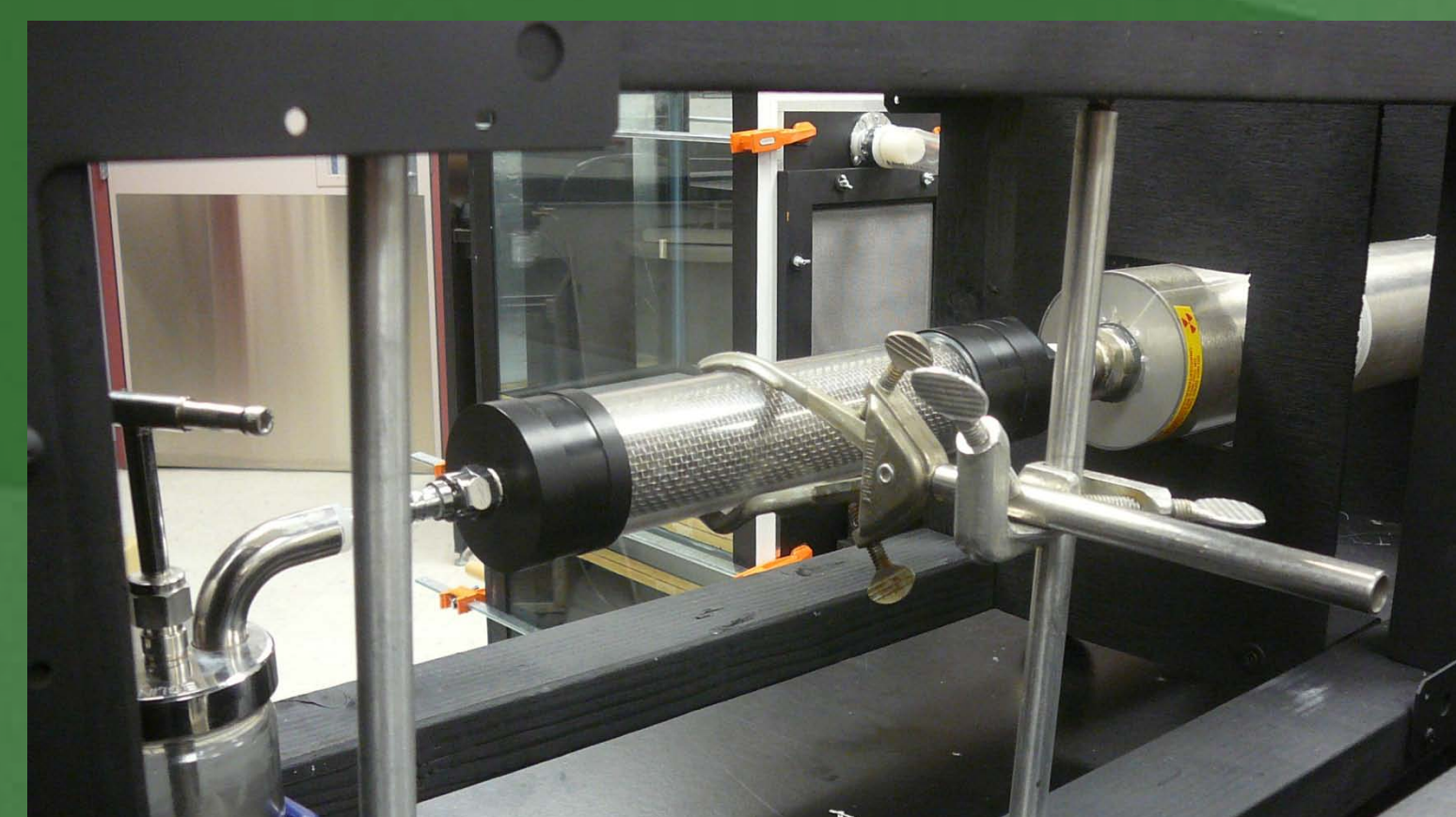


Figure 3. Generation Train

Sampling Procedures

An average number concentration was taken over 30 minutes for background concentrations inside and outside the respirator. Once background levels were established, the aerosol was generated over a period of 30 minutes or until concentration levels in the test chamber were stabilized. A ten minute sample measuring the concentration inside and a ten minute sample measuring the concentration outside of the respirator were repeated five times. This procedure was performed for 0.5, 1, and 2 μm PSL spheres with the stapled areas of the filter intact. The entire process was repeated for the each respirator after sealing the stapled areas of the filter medium with silicon rubber.

Results

The average efficiencies at 0.5, 1 and 2 μm PSL spheres for each respirator tested (Figure 7-10) as well as the average efficiencies of the four respirators (Figure 11) are presented below.

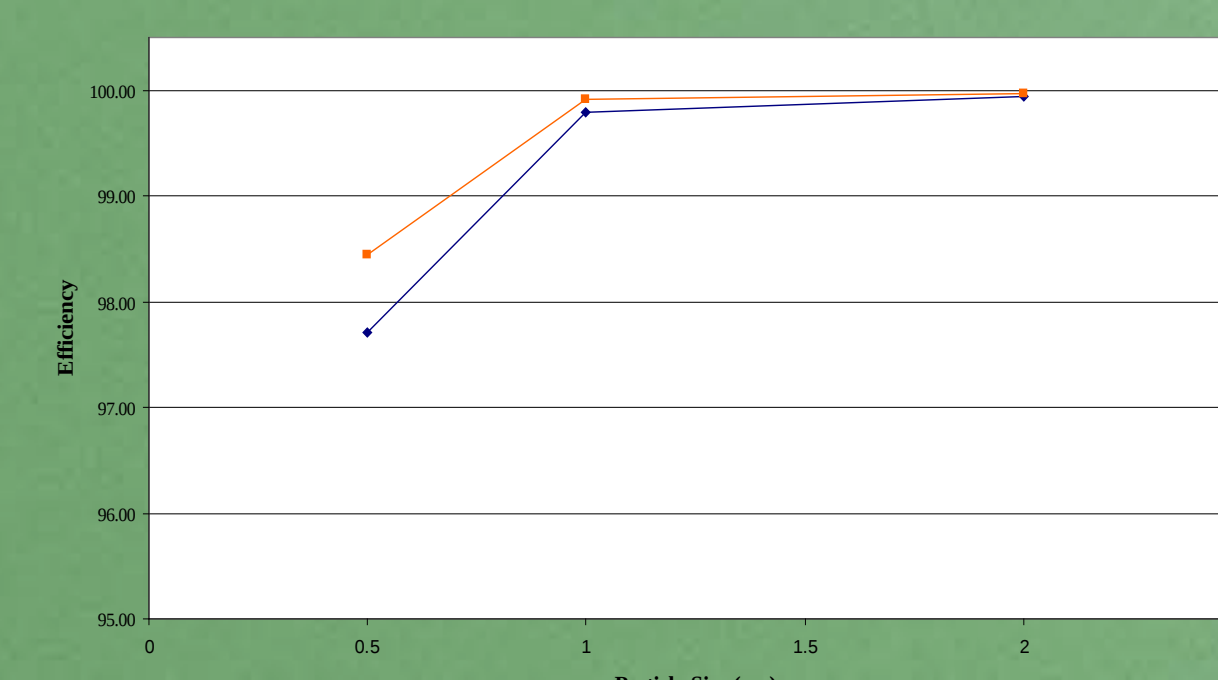


Figure 7. Efficiency for Respirator 1 (n=5)

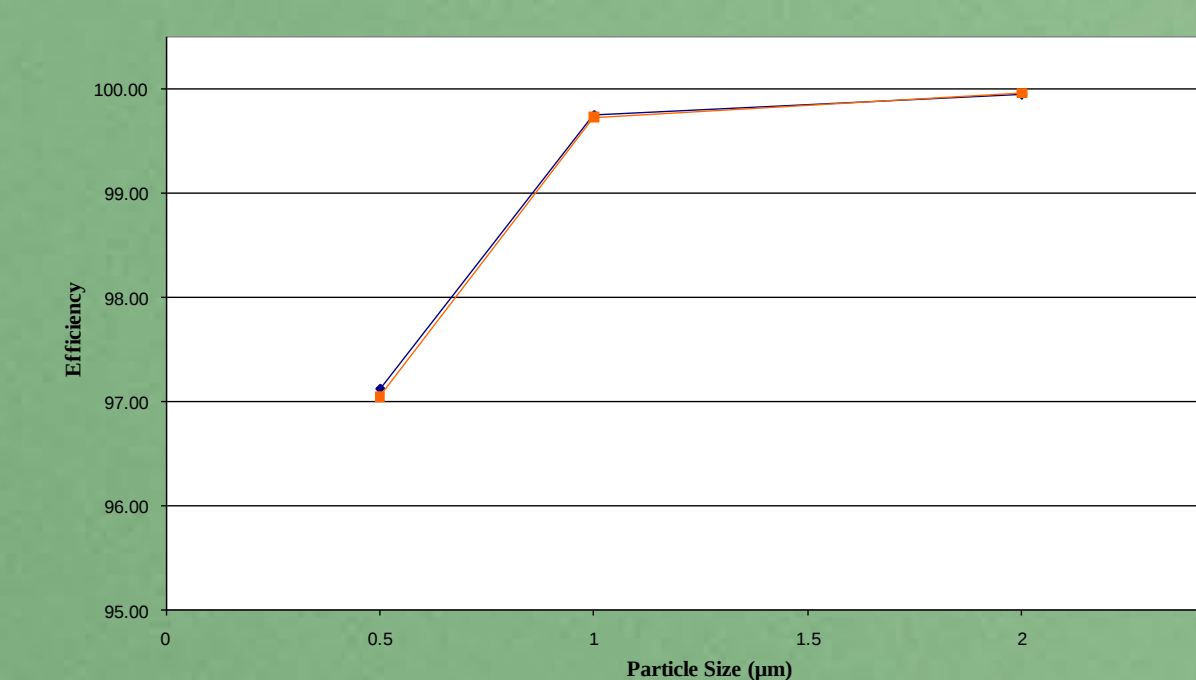


Figure 8. Efficiency for Respirator 2 (n=5)

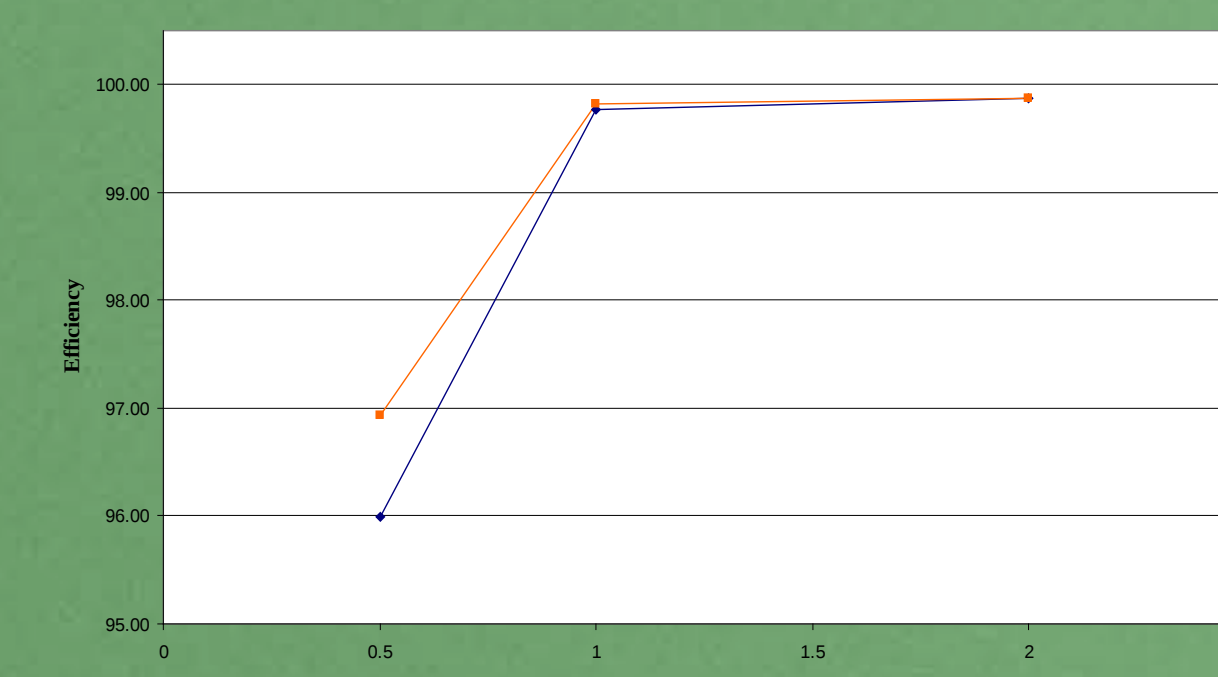


Figure 9. Efficiency for Respirator 3 (n=5)

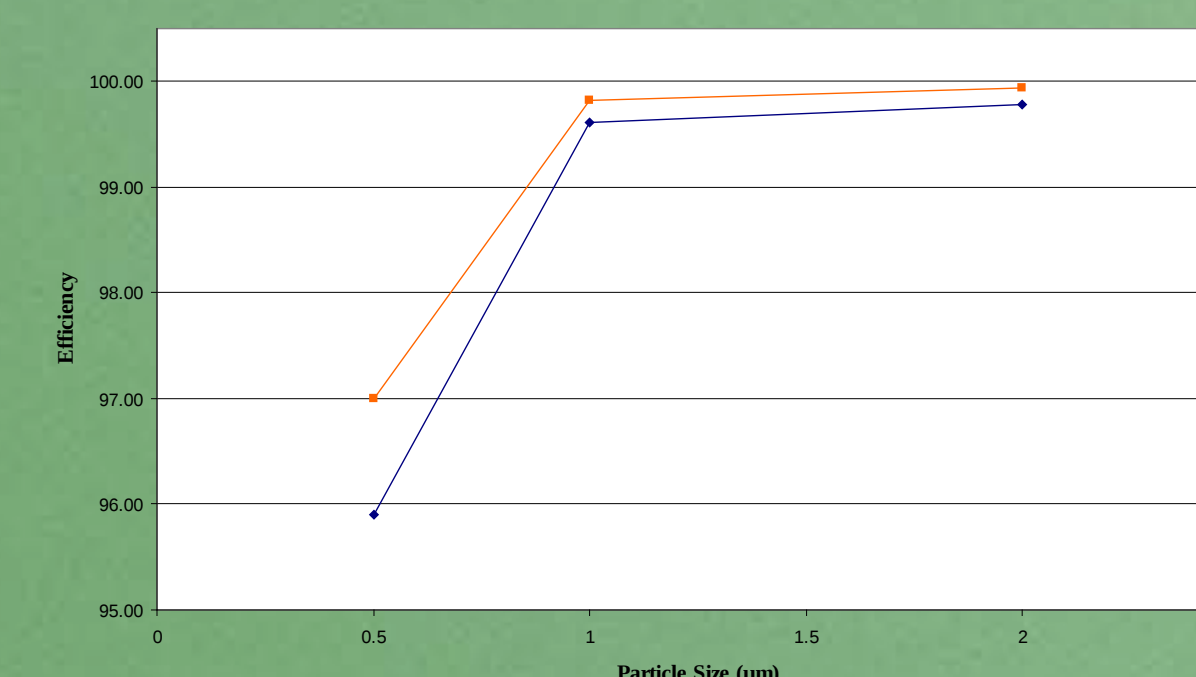


Figure 10. Efficiency for Respirator 4 (n=5)

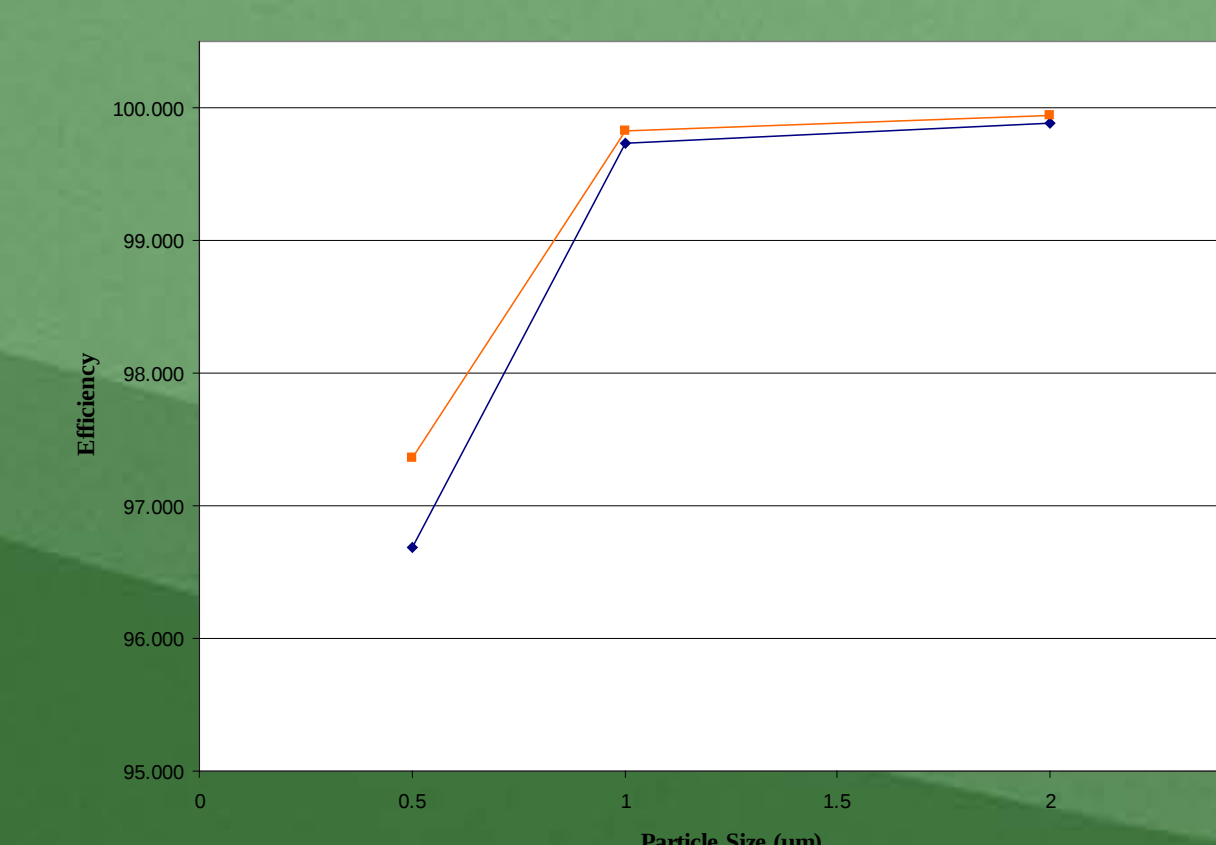


Figure 11. Average Efficiency for all Respirators (n=20)

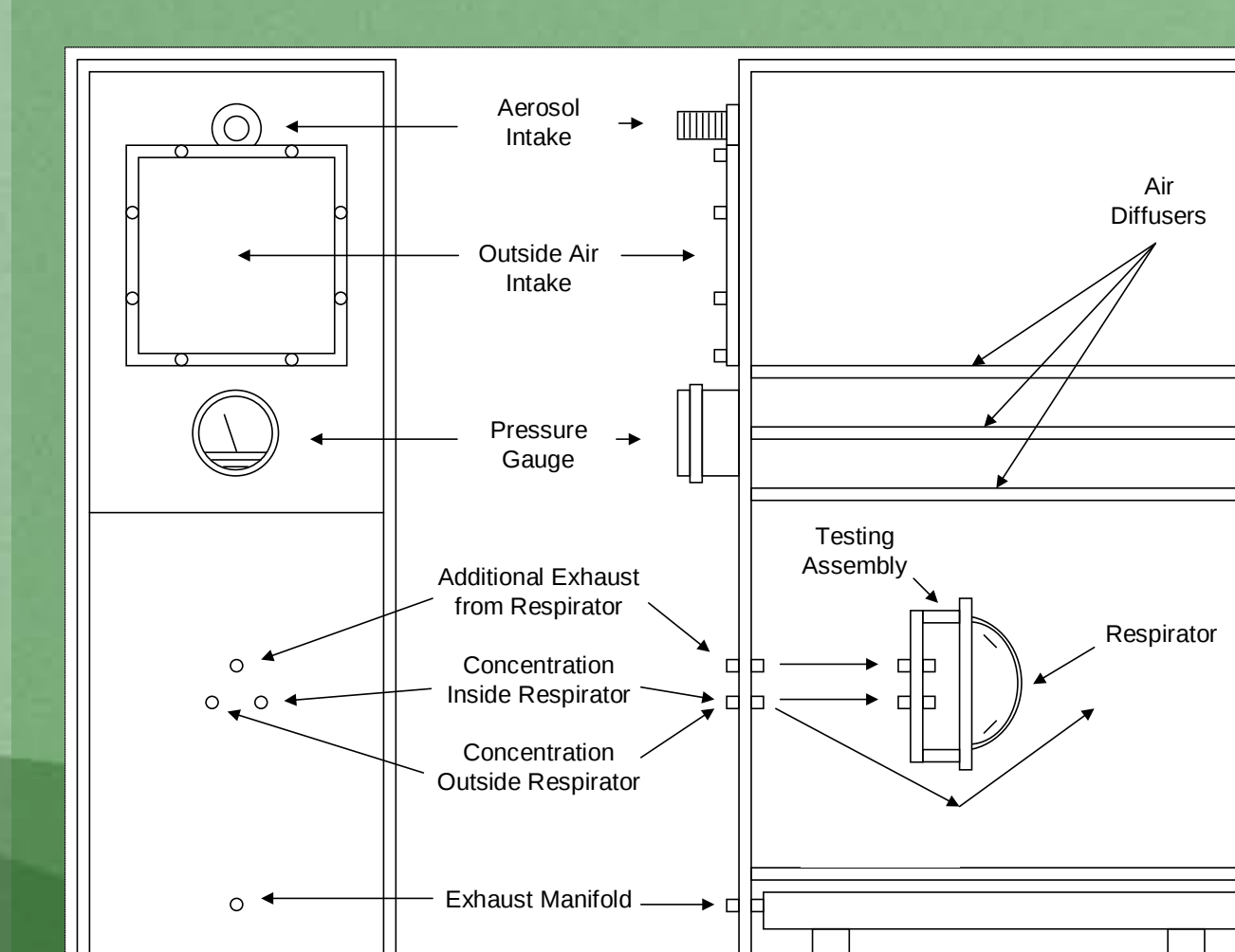


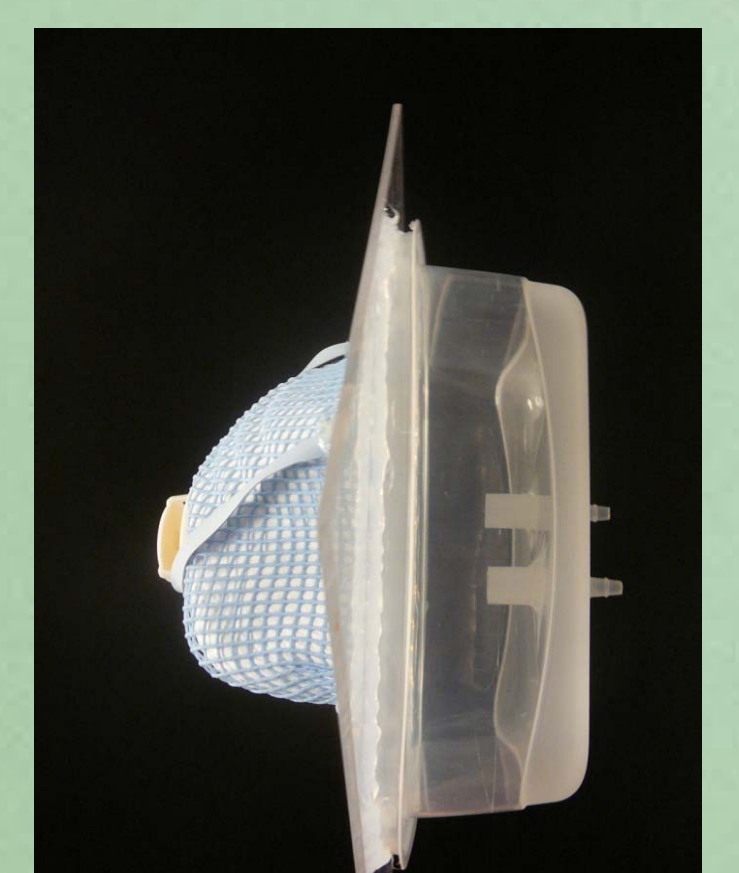
Figure 4. Test Chamber and Components

Statistical Analysis

A Tukey honestly significant difference (HSD) multiple comparison test showed that, when challenged with 0.5 μm PSL spheres, the efficiencies of the unsealed and sealed respirators were significantly different from the efficiencies of the respirators challenged with 1 and 2 μm PSL spheres at an alpha value less than 0.05. Furthermore, respirators showed significantly different efficiencies when challenged with 0.5 μm PSL spheres before and after sealing the stapled areas of the filter.



Figure 6. Respirator and Testing Assembly



Conclusions

At all particle sizes, the filter penetrations observed in this study did not exceed 5%. NIOSH mandates an efficiency higher than 95% for certification of N95 filtering facepiece respirators. Therefore, the study suggests that the penetrations through the staple openings are not a concern at particle sizes larger or equal to 0.5 μm . However, the detected penetration will have a cumulative effect when added to other sources of single use respirator leakage in the field. More testing is necessary to determine if there is greater penetration through the stapled areas at particle sizes smaller than 0.5 μm . Although penetration through the stapled areas may be insufficient to cause immediate concern at 0.5 μm , the study suggests that a challenge aerosol of smaller particles may show increased penetration through the stapled areas in comparison to that observed at 0.5 μm .



Figure 5. Test Chamber